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# Combustion products toxicity risk assessment in an offshore installation

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ABSTRACT

Products of a hydrocarbon fire accident have both chronic and acute health effects. They cause respiratory issues to lung cancer. While fire is the most frequent phenomenon among the offshore accidents, predicting the contaminants' concentration and their behavior are key issues. Safety measures design, such as ventilation and emergency routes based only on predicted contaminants' concentration seems not to be the best approach. In a combustion process, various harmful substances are produced and their concentration cannot be added. The time duration that any individual spends in different locations of an offshore installation also varies significantly. A risk-based approach considers the duration a person is exposed to contaminants at various locations and also evaluates the hazardous impacts. A risk-based approach has also an additivity characteristic which helps to assess overall risk.

Through the current study, an approach is proposed to be used for risk assessment of combustion products dispersion phenomenon in a confined or semi-confined facility. Considering CO, $NO_2$ and $CH_4$ as the contaminants of concern, the dispersion of the substances over the layout of the facility after a LNG fire is modeled. Considering different exposure times for three major parts of the facility including the processing area, office area and the accommodation module, the risk contours of CO, $NO_2$ and $CH_4$ over the entire facility are developed. The additivity characteristic of the risk-based approach was used to calculate the overall risk. The proposed approach helps to better design safety measures to minimize the impacts and effective emergency evacuation planning.



*Keywords:* CFD; Pool Fire; Combustion products; Toxic dispersion; Acute effects; Risk-based approach

## 1. Introduction

Harmful airborne contaminants in a process facility are a matter of concern. It is important to provide a safe environment for personnel working in a processing area. Predicting the risks caused from airborne toxicants is a useful approach to emergency preparedness.

Offshore personnel spend most of their time in a semi enclosed processing area or an enclosed office/residential area. Thus, it is important to minimize harmful effects during an accidental event. According to Pula et al. (2005), fire is the most frequent accident occurring on offshore installations. One of the main sources of concern is the combustion of hydrocarbons due to fire accidents (Hartzell, 2001). Thus, there is a need to carefully assess the hazards caused by a fire accident such as heat radiation and airborne toxic contaminants (combustion products).

An example of toxic dispersing in an industrial accident is the massive fire which occurred at oil storage in 2005 at Oil Storage Depots (Buncefield, Hertfordshire, England). The production of smoke and combustion products caused environmental problems and health issues over the plant and near-by areas showing the need to estimate the toxic substance concentration at and around the plant (Markatos et al., 2009). The Piper Alpha explosion in the North Sea is another example of the hazards caused by combustion products. In 1988, the failure of a condensate injection pump caused a leak and was followed by a small explosion. Due to the failure of

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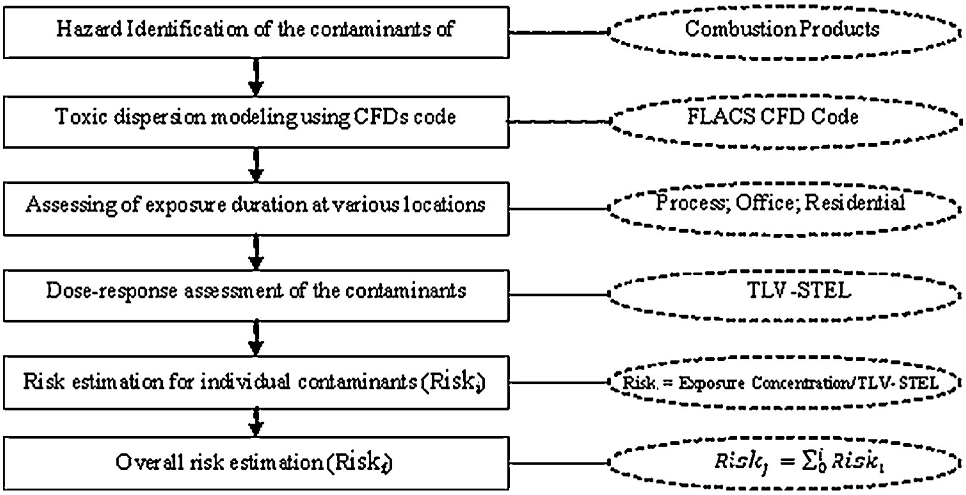


**Fig. 1 – A methodology of toxic risk assessment.**

safety equipment, a series of major blasts occurred followed by a fireball. Then, the failure of the gas pipeline riser led to a massive explosion which was the reason for the collapse of the drilling derrick. The loss of 167 lives in the Piper Alpha disaster was demonstrated to be mainly from the smoke inhalation due to the massive fire (Knight and Pretty, 1997). The release of methyl isocyanate (MIC) as an intermediate product of a pesticide production plant in Bhopal, India in 1984 is another example of such accidents. Dispersing to the nearby town, the released MIC caused the death of 2000–4000 people (Bowonder, 1987). In 1976, the accidental release of dioxin from the Industire Chimich Meda Societa Azionaria in Seveso, Italy was the cause of 200,000 people came into contact with the dioxin cloud. Skin diseases and cancers were the main results of this accident (Assael and Kakosimos, 2010).

Studies on combustion products toxicity assessment are quite limited. Safety measure design and emergency preparedness are not very effective when they are only based on contaminants' concentration. In a study conducted by Markatos (2012), a CFD simulation was performed to model the dispersion of combustion products after a pool fire. The results were used to define two risk zones on the facility. However, only lethal concentration ($LC_1$) was determined to define the risk zones ignoring the exposure time an individual spent at different locations of a facility. Using the $LC_1$ value for the hazard index also suffers the lack of adding the risk values of various contaminants. Personnel spend different time durations in various locations of an offshore facility (different exposure time) and the concentration of various toxic substances cannot be added. As a solution, a risk-based approach helps to consider the time duration when personnel are exposed to air pollutants at different sections of a plant. Additionally, it helps to combine the harmful effects caused by various toxic substances (Markatos, 2012).

According to Srebic and Chen (2002), the application of Computational Fluid Dynamics (CFDs) is a common method of assessing air quality characteristics such as pollution concentration and air flow patterns. CFDs codes were extensively used in dispersion studies such as a liquefied natural gas (LNG) spill (Gavelli et al., 2008), heavy gas dispersion over large topographically complex areas (Scargiali et al., 2005) and indoor dispersion of toxic chemical substances (Kassomenos et al., 2008; Mcbride et al., 2001). The application of CFD codes for the prediction of smoke/combustion products over the offshore complexities is also recommended by HSE (2004). CFD codes have the advantages of low cost, high speed, capability to provide complete information and the ability to model ideal and realistic conditions (Bo and Guo-ming, 2010).

The focus of this study is to develop a methodology to apply a CFDs code to assess the dispersion of combustion products from a fire incident over a platform in combination with a risk-based approach to develop the risk profile. This is helpful for the safety measures design on offshore facilities. It is also useful to plan any emergency actions required on an installation during an accident.

**Table 1 – Emission factors, fuel consumption and the flow rate of $CO$, $NO_2$ and $CH_4$.**

| Emission | Emission factor ($g\,m^{-3}$) | Fuel consumption ($m^3\,s^{-1}$) | Flow rate ($g\,s^{-1}$) |
|---|---|---|---|
| $CO$ | 4.48 | 0.5653 | 2.53 |
| $NO_2$ | 1.344 | 0.5653 | 0.76 |
| $CH_4$ | 0.0368 | 0.5653 | 0.021 |

**Table 2 – Adverse health effects (Abbassi et al., 2012; OSHA, 2003).**

| Health hazard air pollution parameters | Adverse health effects | |
|---|---|---|
| | Acute | Chronic |
| $CO$ | Fast heart rate, low blood pressure, cardiac arrhythmia, dizziness, central nervous system depression, unconsciousness and death | Persistent headache, depression, confusion, memory loss, nausea and vomiting |
| $NO_2$ | Eye irritation, throat irritation, lung irritation and triggering asthma | Obliterative bronchiolitis |
| $CH_4$ | Headache, dizziness, nausea, vomiting, increased breathing rate and unconsciousness | No chronic effects |

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